

Chapter 2

The Discovery of Juno

The specific difference existing between planets and asteroids appears now, by the addition of a third individual of the latter species, to be more completely established, and that circumstance, in my opinion, has added more to the ornament of our system than the discovery of a new planet could have done.

– William Herschel 1805

An Extraordinary Phenomenon

In 1802 astronomers were presented with a cognate pair: Ceres and Pallas were seen to have similar distances from the Sun, similar magnitudes, sizes and perhaps even intersecting orbits. ‘Three’s a crowd’ was a proverb current from the sixteenth century, and although there was no clamor for the two goddesses to have a celestial sibling, a German astronomer at Lilienthal Observatory put that proverb to the test in 1804.

Karl Ludwig Harding (Fig. 2.1) announced his great discovery of the third asteroid to Carl Gauss in terms that were far from triumphal. His letter, dated September 6, 1804, transfers the happiness of the discovery from himself to Gauss as the mathematical calculator. The letter (printed in full in Chap. 8 of this book) opens as follows:

Dearest friend, you have all reason to be happy: there is more for you to calculate: On the evening of September 1, 10h 12', I found a new moving star and have observed it already four times since. It is of 7-8th magnitude, fairly bright and was moving, as required by theory, retrograde with strongly increasing southern declination. You will already find it on my map of the orbit of Ceres and will probably roam in this celestial region for several months.

The letter to Gauss was essentially repeated by Harding in a letter to Zach, who published it in the October issue of the *Monthly Correspondence* (Zach does not give the date of this missive). Harding was very circumspect about his discovery. Even though he observed it five times by September 6, it was not until that date he

Fig. 2.1 Karl Harding

informed the director at Lilienthal, Johann Schroeter. “On September 6, 1804, when Mr. Harding had become certain of such an important discovery,” writes Schroeter (1805:246), “I enjoyed for the first time the inestimable pleasure of observing together with the discoverer the new wanderer.” I find it quite amazing he did not excitedly show it to Schroeter by the third night. (Cunningham 2004)

In addition to the discovery letter addressed to Gauss, we also have the one he wrote to Joseph-Jerome Lalande (1732–1807) in Paris on November 10, 1804 (The first portion of this letter, about Harding’s creation of a star atlas, was printed in the third book in this series). Unlike Piazzi, who informed only Johann Bode and Lalande about his discovery of Ceres, Harding initially sent word to four astronomers: Bode in Berlin, Baron Franz von Zach in Gotha, Gauss in Brunswick and Wilhelm Olbers in Bremen. On September 9 Olbers wrote about the discovery to Zach, who also published it in the October issue of the *MC*.

Even though the number was greater, all the correspondents were in Germany, so Harding obviously felt no requirement to make his discovery known simultaneously all over Europe, waiting a full month before notifying Lalande. The most logical conclusion to be drawn from this is that he wanted German astronomers to consolidate all the initial observations of his discovery so that no other nation had any say in its early study or naming. Here we read what Harding belatedly (and unapologetically) wrote to Lalande:

This enterprise [creation of a star atlas], which procured me a minute knowledge of the starry firmament, furnished me with the opportunity of discovering a new planet. On the 1st of September, comparing the sheet of my little atlas with the heavens, I found, between No. 3 in Mayer’s Catalogue, and a star mentioned in your History, another unknown star,

*which I had never before seen in that place. I marked it in my chart as a star having $2^{\circ} 25'$ right-ascension, and $36'$ of northern-declination, without suspecting any singularity. On the 4th of September this star was gone, but at 2° of right ascension, and $1'$ of northern declination, I observed another star, which I had not perceived three days before. I began to suspect a motion in the unknown star, and the more strongly, as I found neither of the two stars marked in a chart drawn last year, though I had introduced into it stars of a much feebler light. I therefore hastened to observe it with the micrometer, to determine its position; but a fog intervened, at the moment when I had brought the star to the field of my telescope. I waited with impatience till the following day, and found that the star had changed its place considerably. The micrometer gave me its position for 11h 12' 45" mean-time, $1^{\circ} 51' 51''$ right-ascension, and $11' 26''$ south declination. After this observation I no longer doubted that it was a moveable star, and perhaps a planet; because, when seen by our largest telescopes, it had neither tail nor nebosity, so that it could not be a comet. I hastened to apprise Messrs. Olbers, Gauss, Bode and Baron Von Zach, of the circumstance. The first commenced his observations the 7th of September. I prosecuted mine till the 27th, when I was informed that M. von Zach had commenced a course of observations with capital instruments. [Letter quoted in *The Monthly Magazine* (1805) and Wilkes 1812.]*

Gauss, in a jubilant letter of September 25, 1804 to Maskelyne, called the existence of a third planet between Mars and Jupiter an “extraordinary phenomenon.” (See Chap. 7 for the full text.)

An Accidental Discovery

“I know of nothing which led Mr. Herschel to direct his optic tube at this star more than mere accident.” So writes Benjamin West (1788:165) about the discovery of the planet Uranus in 1781.

Unlike the discovery of Vesta, the discovery of Juno 23 years after that of Uranus was accidental. The English science popularizer Thomas Dick (1840:75) made mention of this in the context of what would be required to make more astronomical discoveries, including more planets.

Several discoveries have been made by accidentally directing a telescope to certain parts of the heavens...and several of the new planets which have been discovered within the last fifty or sixty years, were detected when the discoverers were employed making observations with a different object in view...It was while Mr. Harding of Lilienthal, near Bremen, was forming an atlas of the stars so far as the eighth magnitude, that, on the 1st September, 1804, he discovered in the constellation Pisces the planet Juno, one of four asteroids situated between the orbits of Mars and Jupiter.

If, therefore, instead of a few individuals occasionally engaged in surveying celestial phenomena, and chiefly confined to a small portion of Europe,—were thousands and tens of thousands of telescopes daily directed to the sky from every region of the earth, and were distinct portions of the heavens allotted to distinct classes of observers, as the object of their more immediate research, every portion of that vast concave, with the numerous globes which roll within its wide circumference, as far as human vision assisted by art can penetrate, would ere long be thoroughly explored, and its hidden worlds disclosed to view. The undiscovered planets belonging to our system, if any still remain, would be brought to view.

His suggestion of allotting sectors of the sky to specific observers to search for new planets reflects exactly what Baron von Zach suggested when he formed the

Vereinigten Astronomischen Gesellschaft on September 21, 1800. Popularly known in later years as the Celestial Police, it never fulfilled its lofty ambitions, but it showed the way for future international cooperation.

The Imperious Queen

The name Juno was first given to Piazzi's discovery of Ceres. "In view of the day of his discovery, the name, Juno, proposed for him, was very appropriate. Juno Lucina appeared, as it were, at the birth of the new century." (Moerlin 1804:117). This pun refers to the fact that Juno Lucina was the goddess of childbirth. Some confusion was likely engendered in the public mind when it was recycled 3 years later for Harding's discovery. Here we see an early use of the name from the Hamburg newspaper on December 6, 1801:

From Berlin they wrote that the celebrated astronomer Bode received two letters from Palermo from Mr. de Piazzi, where he agrees with the said astronomer that the star discovered on 23 January last is a planet. The German Astronomers plan to call it Juno, by analogy with the names of the other planets, but Mr. de Piazzi wishes it will be called Ceres Fernandia, alluding both to Ceres ancient domain of Sicily and to the reigning monarch.

This notice was printed across Europe. For example, on January 12, 1802, it was in the *Gazeta de Lisboa* in Portugal. It was printed there just 11 days after Olbers had recovered Ceres for the first time since its last appearance on January 23, 1801, but of course the printers of the newspaper in Lisbon did not know that. Readers were left wondering if the new planet would be called Juno or Ceres Fernandia. Piazzi actually named it Ceres Ferdinanda, but two letters got dropped by the time it reached the far western shore of Europe. In the end, Ceres won the day. The discovery of Juno would have to wait until 1804.

Despite his status as a planetary discoverer, Harding was very uncertain of his status in the professional astronomical community. Does the assistant of the great Johann Schroeter (himself an amateur astronomer in the grand tradition) have the right to give voice to his own choice of a name? Apparently not, as he rejected his own choice of Themis, and then waffled on what it should be called. We see in the following letter to Gauss that he also initially rejects the name Juno as suggested by Olbers, but relents as a posthumous honor to Ernst II, Duke of Gotha, who was himself an amateur astronomer. The duke's suggestion of Juno was the one he offered for an unknown object between Mars and Jupiter, an object Zach had deduced the orbital elements for in 1786. His legacy was very much on Harding's mind, as the duke had died on April 20, 1804, just a few months prior to the discovery of the third asteroid, so in death the Duke finally got to name a new planet.

I would gladly relinquish this honour of picking a name if I was granted a voice. Dr. Olbers suggested Juno; but does this small star deserve the name of this grand goddess? Since the late Duke of Gotha already considered this name for a future planet, I believe it a right to honour him by this posthum. Without taking this into account I would agree to your choice and prefer Hebe. The other day I considered Themis, who was a sister of Ceres

and Pallas, but Hebe and Juno convinced me. You are also an admirer of this amiable gender, aren't you? Please make sure that it is called either Hebe or Juno. (September 13, 1804; Harding to Gauss)

Gauss wrote to Olbers on September 21, 1804:

I've just received a letter from Zach, the first one this year, containing the following observations of the new star: (I wish Mr. Harding would soon give it a name, at least as soon as its planetary nature is definitively demonstrated; I suggested the name Hebe to him.)

Gauss made it clear to Harding that he had the obligation to name his own discovery. While responding to Harding, Gauss also made his views on nomenclature clear to Great Britain's Astronomer Royal Nevil Maskelyne (1732–1811) in a letter of September 25, 1804. The genealogy of Hebe, Gauss' suggestion, exhibits a close link with Olbers' suggestion of Juno. Hebe was the daughter of Zeus and Hera in Greek mythology, but in Roman mythology, Hera was equated with Juno.

As there seems to be little doubt, that this star is really a permanent planet, a denomination soon must be thought of. I have proposed the name of Hebe to Mr. Harding on account of the bright and fair light of the planet, not unworthy of the goddess of Youth. If this name should be accepted (of which naturally Mr. Harding the discoverer must remain arbiter), a flower would not be an unbecoming symbol.

Harding responded to Gauss 2 days after this missive was sent to Maskelyne. Harding did not entirely give up on the name Hebe, which he proposes as the name of the fourth – and yet undiscovered – asteroid. Here he calls himself an old bachelor, aged only 39. He did eventually get married and had a child, but the girl died at age 14. Excessive grief hastened his own demise at age 69.

So you are insisting too that I christen my child? Well, I accepted, taking into account your Hebe and Dr. Olbers' suggestion of Juno. It is true, the bossy, several times spurned woman deserved to get jilted: but she is also the patroness of beautiful girls and women, who has to be courted for their sake in order to be favoured by her beautiful clients. I am an old bald confirmed bachelor and have to be content if even the deserted smiles at me. But more, this name bears resemblance to that of a dear little doll, whose fire eyes, similar to those of Juno, could set a world on fire. Isn't it equitable to honour her in this name? But this is the most unimportant reason, it would be immodest to take advantage of your kindness and snatch away your blossoming Hebe. You should keep it for a fourth sister with whom you will acquaint us. [The full text of this letter is in Chap. 8 of this book.]

As the letter attests, it was Olbers who suggested the name Juno to Harding. On October 16, 1804, Harding made it clear to Gauss he really didn't care what his discovery was called: "Do you know whether Mr. von Zach approves of the name Juno? As far as I am concerned she might be called as he prefers." Truly a stark contrast with Piazzi. He was so insistent his discovery be called Ceres Ferdinanda by everyone because he had the right to name it "like something I own." Piazzi himself received welcome intelligence from an unknown source about the proposed name for the new planet. On Oct. 25, 1804, he wrote to his friend Barnaba Oriani in Milan it will "probably be named Proserpina, Panes or Triptolemo, so it will be in the same history as Ceres." In mythology, Proserpina was the daughter of Ceres (or Demeter). Triptolemus learned the art of agriculture from Demeter, who gave this knowledge to the Greeks. Panes were spirits who protected the flocks of the farmers.

Yet another name was floated: Pomona was the suggestion of the German astronomer Johann Sigismund Huth (1763–1818). His choice was likely due to the fact that Pomona, the Roman goddess of fruit and orchards, was often associated with the Greek goddess Demeter whose Roman counterpart is Ceres.

It must have come as a surprise to all that Harding actually named his discovery Juno-George (or Juno-Georgica), after George III of Great Britain. The king was the patron of his employer, Schroeter. The hyphenated name became evident when Schroeter (1805) published his book on Ceres, Pallas and Juno. The name does not appear in his private correspondence, and it never appeared in print again outside of a brief mention in *The Eclectic Review* (1807:183). In any case, Lalande (1805:130) rejected the name Juno.

It has already been in agitation to give an ancient name to the new planet: it was proposed to call it Juno. For my part I shall never call the planets recently discovered by any other names than Herschel, Piazzi, Olbers, and Harding.

The subject of honor due to astronomers was noted in *The London Magazine* (1824): “Shakespeare, it may be said, has almost exhausted the kingdom of character; and an author who in the present age discovers a new one, merits the same honour as an astronomer who discovers a new planet.”

The naming of Juno generated controversy for many years. Why, it was asked, should the exalted name of the Queen of Heaven (Fig. 2.2) be given to such a miserably small object? Harding himself made the point, as we have already seen: “Does this small star deserve the name of this grand goddess?” The argument was made most forcibly by an anonymous author in a book entitled *A Fantastical Excursion into the Planets* (1839:98):

Did they really place that high imperial dame, the sister and the wife of omni-domineering Jove – did they really settle her on such a wee ball, and among such inferior, yet such holy, from her in character, so totally differing company [i. e., Ceres, Pallas and Vesta]. What? That imperious queen, whom to rule the sovereign lord, ay, the thunderer himself, was scarce potent enough; to let that high controlling matron dwindle and shrink into such a shabby parcel of scarce connected matter, not even in the wide aerial ocean visible to naked eyes. Let your fancy place her but for a moment at the side of her lord’s prodigious bulk, and then see what a contemptible fragment, even near one of his least satellites she would appear. So times, alas! may change, that verily the pre-eminent of celestial queens must be well content, if but to get a place among subaltern deities, and thus, after all, be obliged to astronomers for reviving her name, and by their bounty get an abode assigned, though with such degrading rank.

The Symbol for Juno

The subject of an appropriate symbol to denote Juno was also a matter attended by some dispute.

According to Zach (*Monthly Correspondence*, Nov. 1804) Harding chose the symbol.

Fig. 2.2 The Queen of Heaven, Juno, as depicted on a 19th century perfumery shop sign. Painting by Jakab Warschag, Kiscelli Museum, Budapest



The discoverer of this new planet, Inspector Harding, chose Juno as the name for this newly discovered planet and a scepter crowned with a star ✧ as its symbol. This symbol is very easily written and is subject to no confusion with other symbols.

However, a letter of September 26, 1804, from Olbers to Gauss shows this is mistaken. It was Gauss who created the symbol.

As a symbol for Juno I'd like to propose yours with a star-topped dagger to Mr. Harding. This symbol is easily drawn; it looks quite good compared to the others and can't be mistaken for any others. The star on the dagger would suggest Juno's asteroid-like nature.

To add further confusion, Gauss wrote to Maskelyne just 1 day earlier (September 25, 1804) suggesting a very different symbol.

I have proposed the name of Hebe to Mr. Harding on account of the bright and fair light of the planet, not unworthy of the goddess of Youth. If this name should be accepted (of which naturally Mr. Harding the discoverer must remain arbiter), a flower would not be an unbecoming symbol.

Fig. 2.3 Juno symbol
from Poppe (1822)



Fig. 2.4 Juno symbol
from Kendall (1845)



Surprisingly a third symbol can be found in a book by Johann Heinrich Moritz von Poppe (1822:14). It looks like the scepter (or dagger) has the star symbol superimposed on it, instead of crowned by it. Rather, we see it crowned by an upward curve (Fig. 2.3). There was yet another contender. Kendall (1845: 251) says “Her astronomical emblem is by some a sceptre surmounted with a star, token of magnificence* ; by others, a mirror, crowned with a star, the emblems of beauty and power.” (Fig. 2.4) In a modern Russian book, Simonenko (1985:20) gives a six-pointed star for Juno *sans* the scepter; and the symbol for Ceres becomes the mirror image of the one used elsewhere.

Physical Properties

An excellent synopsis of our understanding of Juno was printed in the London publication *A Dictionary of Mechanical Sciences, Arts and Manufactures* by Alexander Jamieson (1829, 1:534). It considers color (the supposedly reddish appearance), diameter and atmosphere. It was, unfortunately, sadly misinformed by the fantasies of Schroeter. It is quite astonishing how the editor (of Sion Hill, Middlesex) could in same breath say Juno has no nebulous appearance and yet claim it has a dense atmosphere. It begins with Juno’s color, a matter considered separately in this chapter.

The planet Juno is of a reddish colour, and is free from that nebulosity which surrounds Pallas. Its diameter, and its mean distance, are less than those of the other new planets. It is distinguished from all other planets by the great eccentricity of its orbit; and the effect of this is so extremely sensible, that it passes over that half of its orbit, which is bisected by its perihelion, in half the time that it employs in describing the other half, which is farther from the sun. From the same cause, its greatest distance from the sun is double the least distance, the difference between the two distances being about 127 millions of miles. Though there is no nebulous appearance around the planet Juno, yet it appears, from the observations of Schroeter, that it must have an atmosphere more dense than that of any of the old planets of the system. A very remarkable variation in the brilliancy of this planet has been observed by this astronomer. He attributes it chiefly to changes that are going on in its atmosphere, though he thinks it not improbable that these changes may arise from a diurnal rotation performed in 27 hours.

The real diurnal rotation of Juno equals 7.21 h, not 27 h. The spurious figure of 27 h was widely reprinted. The figure was quoted in *A System of Mechanical Philosophy* (1822, 3:69). It was published under the name of the Scottish physicist John Robison (1739–1805), but appeared 17 years after his death and was updated

by his fellow Scot, the inimitable David Brewster. It is in another 1822 book, this time in America by the Boston author John Hubbard Wilkins (1822:15). A table in the London publication *The Ladies' Diary* (1839:2) has it too; inclination of the axis to the orbit is completely unknown for the four asteroids according to the table, but for "time of rotation on axis" Juno gets the number 27. Schubert (1826:97), Mitchell (1831:85) and Vose (1832:63) used the 27 h figure as well.

This rotational period of Juno had a long and checkered life. Like an old warhorse, it was trotted out again in 1850 by Elias Loomis (professor of natural philosophy at the University of the City of New York) as the supposed period of what he termed 'the asteroid planet.' As Kirkwood (1851:397) rightly observes of this supposition by Loomis, "If we admit the correctness of Schroeter's inference (which is doubtful), it can afford no evidence whatever, that the *original* planet revolved in the same or nearly the same period."

The diameter of Juno was quoted with wildly differing figures. Schroeter measured its diameter (including a spurious atmosphere) to be 1446 miles. Most publications quoted figures based on this. An English publication *Pantologia* (1819) claims "Its real diameter Lalande says is about 1550 miles." *Pantologia* was edited by John Mason Good (American Philosophical Society), Olinthus Gregory (Royal Military Academy, Woolwich) and Newton Bosworth (of Cambridge). A similar figure, 1545, was quoted in Wilkins (1822:23) A diameter of 1425 miles was quoted without a source by Blunt (1840:34).

At the other end of the size spectrum (and closest to reality), a writer in *The Magazine of Popular Science and Journal of the Useful Arts* (1837:349) said that "The largest of them, Juno, cannot have a real diameter of more than 100 miles, or 1/80th that of the earth. If this be the case, her surface is only the 1/6,400th that of the earth, and her bulk the 1/512,000th part."

Juno, when favorably situated in respect to Earth in 1843, was measured by Johann Heinrich von Maedler (1846: 200–203) to be 370 miles in diameter. The German-born Maedler (1794–1874; Fig. 2.5) became director of the Dorpat (Tartu)

Fig. 2.5 Johann Heinrich von Maedler



Observatory in Estonia in 1840. We now know Juno has an irregular shape denoted as a triaxial ellipsoid given by $198 \times 165 \times 124$ miles ($320 \times 267 \times 200$ km) with an overall diameter of 144 miles, or 233 km. The shape of Juno was a particular study of Joshua Prusol (1879), who believed it to be irregular due to the accretion of smaller asteroids. His views on how Juno might one day achieve a spherical shape, and thus join the ranks of the primary planets, can be found in Appendix 2 of this book. Of particular note, Prusol’s work presages the currently accepted definition of a planet.

Orbital Properties

Olbers wrote in admiration to Gauss on September 30, 1804, on his development of the elements of Juno. “It’s astonishing and almost unbelievable to be able to determine already a planet’s orbit so accurately using 16-day observations obtained mostly with a circular micrometer.” Zach was equally ecstatic, writing to Gauss on September 29, 1804. “One hardly knows what is more astonishing: the three newly discovered planets, Dr. Olbers’ prophecy which has come true or your *tour de force*, the elliptical orbit of the new planet!” (See Chaps. 7 and 9 in this book, respectively, for the full text of these letters.) Table 2.1 gives the early elements of Juno by Gauss and Johann Burckhardt (1773–1825) in Paris.

Gauss also gave Olbers very preliminary elements on September 21, 1804, that differ considerably from his official Elements I. These initial figures are given in Chap. 7.

- Elements I are from September 1804.
- Elements II are from September 1804.
- Elements III are from October 1804.
- Elements IV are from December 1804.
- Elements by Burckhardt are from December 1804 (see Burckhardt 1807a, b).

The orbit of Juno (Fig. 2.6) was a wonder of the Solar System, according to a dramatic description by Duncan Bradford (1843:174).

It is distinguished from all the other planets by the great eccentricity of its orbit; and the effect of this is so very sensible, that it passes through the half of its orbit which is bisected by its perihelion in half the time that it employs in describing the other part, which is farther from the sun. From the same cause, its greatest distance from the sun is double the

Table 2.1 The first four elements of Juno derived by Gauss and one by Burckhardt

	I	II	III	IV	Burckhardt
Aphelion	244° 51' 36''	231 38 1	233 56 6	233 23 47	232 49
Node	171 48 24	170 46 41	171 0 0	171 4 12	171 6 0
Incl.	15 12 39	12 19 43	7 8 10.7	13 4 9	13 5
Eccentricity	0.313757	0.254964	0.263182	0.256841	0.25096
Semimajor axis	2.882	2.619	2.671	2.672	2.657

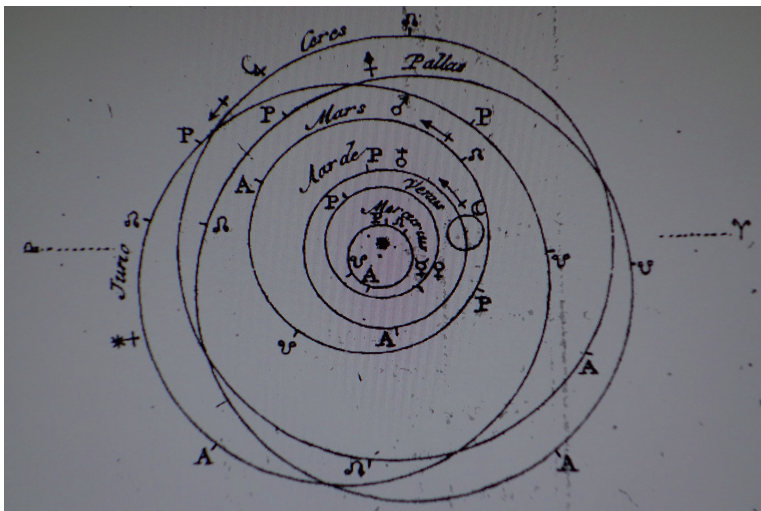


Fig. 2.6 A map showing the orbits of Ceres, Pallas and the newly discovered Juno in a book by Cornelis Covens (1764–1825; 1806). In 1807 Covens lectured about the three asteroids at the Felix Meritis Physics Department of the Athenaeum in Amsterdam (Zuidervaat and Van Gent 2012)

least distance, the difference between the two distances being about one hundred and twenty-seven millions of miles. Its mean distance from the sun is two hundred and fifty-three millions of miles.

Asteroid Orbits and Satellites

Once Juno's orbit was determined, it was naturally compared to that of Ceres and Pallas. To see the big picture, we must leap ahead in time to the discovery of the fifth asteroid, Astraea, which was found in 1845. The American W. S. Mifflin (1846) wrote about the intersection of the asteroid orbits, pointing out a flaw in the reasoning of Dick.

By the distance from the Sun and her [Astraea's] periodic time, she seems as intimately connected with Juno, as Ceres and Pallas are with each other. Their periods differing but 28 days, and their distances 0.03, as the eccentricities of their orbits are considerable and very nearly equal, while their perihelions lie in opposite regions of the heavens, it follows that their orbits cross each other in nearly opposite points, to wit: in Leo and Aquarius.

The intersection of orbits is not, however, peculiar to these two planets, but is common to all the members of this family, each of which, in its annual revolution, crosses the orbit of one or more of the rest; and here I cannot help noticing an error, which has crept into that very interesting and popular work, Dr. Dick's Celestial Scenery.

The exceptionable passage follows:

'Juno is further from the Sun in her aphelion, than Ceres in the same point of her orbit; and Vesta is further from the sun in her aphelion, than either Juno, Ceres or Pallas, at their

perihelions. The perihelion distance of Vesta is greater than that of Juno or Pallas. Hence Vesta may sometimes be at a greater distance from the sun, than either of the other three, though her mean distance is less than that of either, by millions of miles, so that the orbit of Vesta crosses the orbits of all the other three; therefore, it is a possible circumstance, that a collision may take place between Vesta and either of the other three, should they happen to meet at the intersection of their orbits.'

The facts stated by Dr. Dick are correct, but the inference in respect to the intersection of orbits is only true in the cases of Juno and Pallas. But because the greater axis of Vesta's orbit lies nearly at right angles with that of Ceres, it will not do to compare her aphelion distance with the perihelion distance of Ceres, the true comparison lying between the aphelion distance of Vesta and the mean distance of Ceres, the latter of which distances is considerably the greater; and hence, though the two orbits approach very nearly in long. 90 to 100, they do not cross; but that of Vesta remains within that of Ceres throughout their entire revolutions.

This is the only exception to the fact, that the orbit of each of these new planets crosses the orbits of all the rest. The intersections of Astraea and Juno have been noticed, that of Astraea and Pallas likewise take place in nearly opposite points in sign 6 and 12.

Astraea likewise crosses the orbit of Ceres in about long. 5 and 115, and though her mean distance from the sun is greater than Vesta's by many millions of miles, while her perihelion lies in the same quarter of the Heavens, yet, by reason of her greater eccentricity, her orbit runs within that of Vesta, from about long. 170 to 250, nearly one-fourth of her whole circuit.

This analysis leads Mifflin to the most astonishing suggestion ever made in the early nineteenth century about the mutual gravitational interaction of the asteroids:

This intersection of orbits must however be understood with some allowance. If they all lie in the same plane, the intersection would be absolute; and if two planets should arrive at an intersection at the same time a collision must take place; but since no two orbits lie in the same plane, their intersection with each other, considered as lines, can be true only in the possible case of the points of intersection falling upon the line, in which the planes of the orbits intersect. In all other cases the two planets, though apparently occupying the same point when viewed in a line perpendicular to the plane bisecting the angle of intersection of their orbits, will still be separated by an interval equal, at least, to the difference in their latitudes. In the case of Astraea, there seems to be no danger of collision; her latitude appears to differ not less than one degree from that of all the others, at the point of intersection, and in the cases mentioned by Dr. Dick, the difference of latitudes is still greater; nor does there appear, from a careful comparison of their elements, any probability of any pair of these bodies coming in actual contact, though there is a bare possibility of so near an approach as to convert the smaller of the two into a satellite of the larger.

William Herschel was the first to look for moons orbiting an asteroid when he studied Ceres in 1802, but here we see the first explanation coming from the realm of celestial mechanics to actually propose how such an asteroidal satellite might arise. Mifflin concludes his paper thus:

The orbit of Astraea agrees with the supposition of a common point of re-union among all the different fragments of the large planet from which these smaller ones have been supposed to have been severed. The nearest approach of all the orbits being in the long. 150, where the orbits of Ceres and Juno intersect that of Pallas, lying within, at a distance of 0.4, while Astraea and Vesta lie close together, about midway of the above distance.

Kendall (1845: 255) writes that "The orbits of Pallas and Juno are very eccentric; and, consequently, the intensity of light and heat, and the apparent magnitude of the sun, are very different for them in different parts of their course. The following figure

	Intensity of Light in the		Apparent Diameter of the Sun in the	
	Perihelion.	Apheiaon.	Perihelion.	Apheiaon.
Vesta	22	15	14' 53".8	12' 26".2
Juno	26	9	16 9 .8	9 32 .1
Ceres	16	11	12 32 .5	10 43 .4
Pallas	23	8	15 12 .6	9 17 .6

Fig. 2.7 The maxima and minima values of light received at the asteroids, with Earth =100. Column at right gives apparent diameter of the Sun (From Kendall 1845)

will show the maxima and minima values of these quantities, the average intensity of the light received at the earth being called 100.” (Fig. 2.7)

Regarding the distance of Juno from Earth, during the period 1912 to 2112 its minimal approach was in 1978 at 1.14 AU while subtending 0.63 arcseconds. Its most distant closest approach of an apparition during that period occurred in 1972 at 1.59 AU and 0.46 arcseconds.

The Color of Juno

The idea that Juno appears reddish appears at least as early as Samuel Vince (1749–1821; 1811:233), an astronomer at Cambridge. It was repeated in many subsequent publications, such as Rees (1819); an American book by John Vose (1827: 58), Principal of the Pembroke Academy in New Hampshire; and Blunt (1840: 34). No reliable source was ever offered; a mid-century observer, James Breen (1854: 186), attributed the reddish hue of Juno to William Herschel (1738–1822).

Herschel thought that he perceived a faint red colour in Juno, whilst others have noticed its soft and white light. In favourable occasions, when the planets are bright, some difference may be perceived between their light and that given by neighbouring stars of the same magnitude, and the writer has frequently noticed with the great refractor of the Cambridge Observatory (Fig. 2.8), the quiet, steady, and pale discs of those bodies when contrasted with the brighter and more twinkling and coloured light of the stars. It has been found that there is a variability in the brightness of a few of them on successive nights. This was first remarked in Juno.

Breen (1826–1866) was an assistant at Cambridge Observatory in England from 1846 to 1858. He observed with the famous Northumberland refractor, built in 1836, which had an aperture of 11.75 inches (30 cm), and a focal length of 19.5 feet. The observing program at Cambridge in the 1840s shows the value placed upon the asteroids. “At the beginning of 1841 observations of bodies of the solar system were suspended; an exception was afterwards made with respect to the three planets above-named [Ceres, Pallas and Vesta] on account of their being more favourably situate or observing in that year than they will be in several succeeding years.” (The Church of England Magazine 1842:11) This took place under the directorship

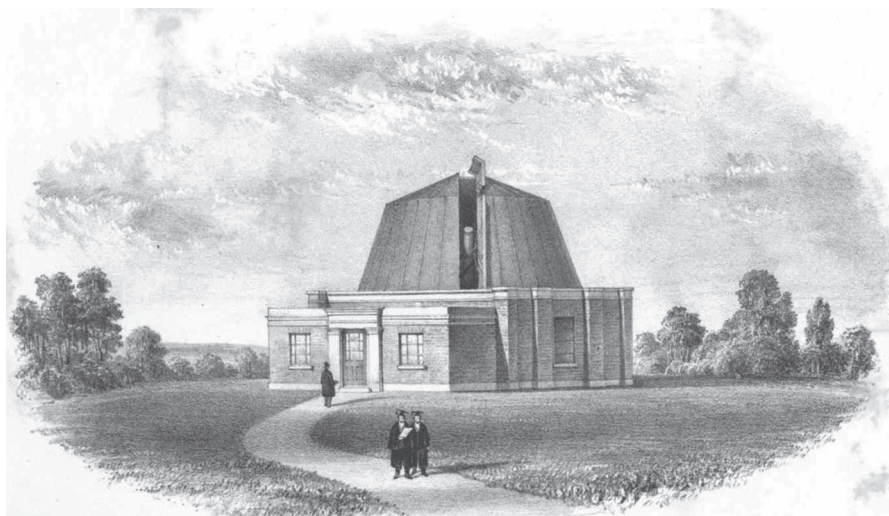


Fig. 2.8 The Northumberland refractor at Cambridge

of James Challis (1803–1882), who succeeded George Biddell Airy (1801–1892) in 1836. An example of the asteroid observations made at Cambridge can be found in Challis (1839).

Herschel's Study of Juno

Herschel was a keen observer of the asteroids and enlisted the aid of his friend Gilpin at the Royal Society for information about Juno. However, Gilpin's reply came too late, Herschel having received a positional measurement from Maskelyne on September 27 that enabled him to conclusively identify Juno. The letter Gilpin wrote in London on November 19, 1804 follows.

I am extremely sorry that after waiting so long endeavouring to obtain for you what you want respecting the new planet Juno, that I am not as yet able to comply with your request. Mr. Harding certainly some time since sent the Elements of the Planet, and I was in hopes of obtaining a copy for you but I now despair of succeeding at least for the present. I send you a diary of its place which will enable you to find it for a few days longer. Also some observations made by Mr. Bode. I understand that its inclination is about 13° . This is all the information I can give you at present. (Fig. 2.9)

Herschel's 1805 paper about Juno is dated December 1, 1804, and covers observations from September 24 through October 11. Its opening paragraphs show Herschel trying to identify the newly discovered object Juno in an unfamiliar star field.

All his subsequent observations are designed to address a single subject – the diameter of Juno. Nowhere does he try to identify any satellites or assign any color. In this his observations are much more focused in their intent than his previous two

Juno			Juno		
Date	Time	Lat. S	Date	Time	Lat. S
2	35.18	10.28	4	35.24	10.28
5	36	38	7	35.27.16	10.28.10
8	38	45	10	35.27.16	10.28.38
11	38	50	13	35.27.16	10.28.38
14	36.14	51	16	35.27.16	10.28.38
17	39	50	19	35.27.16	10.28.38
20	37.7	46	22	35.27.16	10.28.38
23	39	41	25	35.27.16	10.28.38
26	35.15	32	28	35.27.16	10.28.38
29	38	22	31	35.27.16	10.28.38

Fig. 2.9 Positional data on Juno by Gilpin

papers dealing with Ceres and Pallas. A sense of vindication forms his most important conclusion. This is apparent at the beginning of the paper, where he states very matter-of-factly that he was “not much surprised” to learn of Harding’s discovery. In his concluding remarks, Herschel says Juno “resembles in every respect” both Ceres and Pallas. He cites the smallness of its disk, and the considerable inclination and eccentricity of Juno, as putting it firmly in the camp of the asteroids. These characteristics, he specifically asserts, distinguish all three bodies from planets. He describes them as an “ornament of our system,” and thus more important than the discovery of another planet – the same argument he used in his letter to Piazzi, one he tossed aside with disdain. Herschel’s complete study of Juno can be found in Chap. 12 of this book.

Herschel’s paper, which began with *Experiments for ascertaining how far Telescopes will enable us to determine very small Angles, and to distinguish the real from the spurious Diameters of celestial and terrestrial objects*, was met with a scathing commentary in the aptly named *The Critical Review* (1805):

These experiments appear to have been conducted and varied with considerable ingenuity and dexterity, but they afford little interest, and can excite little curiosity even amongst philosophic inquirers. They are however, to the practical astronomer, not without their use; and their indefatigable author has drawn from them, towards the conclusion of his memoir, several results and useful conclusions.

The Critical Review had more to say about the conclusion of Herschel’s paper, which dealt with Juno, but it was also quite derisive.

The last pages of this memoir contain some observations on Mr. Harding’s newly discovered star, called Juno. Dr. H. has amongst the heavenly bodies introduced a new classification, and agreeably (sic) to the conditions of such classification, Juno must be called an asteroid. Dr. H. has rendered to astronomy so much service, that he has some claim to be humoured in what we are certainly disposed to regard as fanciful and whimsical refinements. Controversies concerning words have been so frivolous, so inconclusive, and so numerous, that we studiously wish to avoid adding to their number.

There was continuing and active resistance in England to Herschel’s use of the word asteroid (Cunningham et al. 2009). Fourteen years after this flippant commentary, *The Monthly Review* (1819:98) used a review of a book by R. T. Linnington

(‘a private teacher’ according to the title page) to launch an unprovoked broadside that would have sunk a warship of the day.

We beg to remind the writer that he has not used the proper signs for Juno, Pallas, and Vesta; and we would advise him, and all other authors, to discontinue the use of the term Asteroids as applied to these bodies; they are in every respect planets, as much as any of the other bodies of our system that bear the name. We have always considered the invention of the former designation as an invidious and useless distinction, which ought not to be tolerated.

How the Public Learned About Juno

“The year 1804 was as remarkable as were the years 1801 and 1804, since it presented us with the discovery of a new planet,” said William Butler (1807:344), a teacher of writing, accounts, and geography in Ladies’ schools.

In France, Harding’s discovery was related in the official government publication of the time, the daily *Gazette Nationale ou le Moniteur Universel* (1805a): “Mr Harding, who is Mr. Schroeter’s co-worker at Lilienthal, discovered a new planet which he called Juno. Here are a few words about the history of this discovery...” As a result of his discovery, Harding was awarded the Lalande Prize, an event that was reported by Delambre in the *Moniteur* (1805b). The first French observations of Juno by Burckhardt were then published, and according to the article his orbital calculations corresponded well to those of Gauss (Moniteur 1805c). Finally, Gauss’ latest calculations of the orbit were given in the *Moniteur*, along with his thoughts about Juno’s perturbations: “He volunteers to calculate the perturbations, which it must suffer from Jupiter’s attraction; but the work will take a long time. He believes that there will be several hundred equations for Olbers’ and Harding’s planets.” (Moniteur 1805d). Burckhardt’s early observations were also published in the *Journal de Physique*, and an extract was published in English in William Nicholson’s journal, *A Journal of Natural Philosophy, Chemistry and the Arts* (1805:57):

On the 5th of September, 1804, its right ascension was $1^{\circ} 52'$; declination $0^{\circ} 11'$ north. M. Burckhardt observed it on the 23d of September at $359^{\circ} 7'$ and $4^{\circ} 6'$, whence he concludes that the duration of its revolution is five years and a half. Its inclination 21° ; excentricity one quarter of its radius; mean distance from the sun three times greater than that of the earth.

In The Netherlands, the discovery was reported in a single paragraph in the widely read weekly *Algemeene konst-en Letter-Bode* (1804a). The newspaper followed this up with three more articles. The second (Algemeene 1804b) was more than a page long and included both Harding’s positional data from Sept. 6 to 11, and an observation by Olbers on Sept. 8. The third, “from a High German newspaper” was translated into Dutch in *Algemeene* (1804c). This article was from the Leipzig newspaper quoted in the next paragraph. The fourth was the most extensive of all, reprinting in full (in Dutch translation) a paper from Zach’s *Monthly Correspondence* about Juno (Algemeene 1804d), thus putting this newspaper at the forefront of European publications that disseminated information about Harding’s discovery.

In Pisa, Italy, *Nuovo Giornale dei Letterati* (1804) announced the discovery of a new object by Harding. The following year, *Nuovo Giornale* (1805) gave its readers the view of Lalande that Harding's discovery should not be named after a divinity. Observations of Juno by Harding, Olbers, and Zach, along with the elements by Gauss, were compiled and transmitted to the Italian Society by Joseph Slop de Cadenberg (1740–1808; 1805), the astronomer at Pisa.

In Germany, notice was first given in an article written by Harding (1804) in the *Göttingische gelehrte Anzeigen* (Fig. 2.10). Harding relates his discovery but does not yet offer a name for it in this initial paper.

The GGA published another Juno report in its October 13 issue (Gauss 1804), with the elements and observational data from September and October, as well as the name Juno. Further reports followed in November. The Leipzig newspaper *Neues Allgemeines Intelligenzblatt für Literatur und Kunst* (p. 899) published a paragraph about Juno in its November 17, 1804, issue. This was especially interesting as it reveals Huth believed Juno to be a main planet, more important than Ceres and Pallas:

The planet discovered by Harding is to be named Juno. Dr. Olbers assumes that Ceres, Pallas and Juno are fragments of one planet, that, being larger than a comet, was split into several pieces by some unknown revolution and of which we will most likely find more fragments. According to Hofrat Huth, Juno is the main planet and Ceres and Pallas its satellites or all three are satellites of a planet not yet found. Juno is considerably larger than the two others and not smaller than our Moon. Juno's apparent diameter has been calculated to be 470 German miles, that of Ceres 280 and that of Pallas 251.

In England, the discovery of Juno was related in several publications: *The Scots Magazine*, *The Christian Observer*, *Nicholson's Journal*, and *Tilloch's Journal*. This allows us to compare the extent, accuracy and level of detail given in these important publications in order to assess just what the public was learning. *The Scots Magazine* (1804a) reported the discovery of another new planet named Hercules and followed this up (1804b) with a brief notice that it not yet been seen in England. The spurious announcement of Hercules was reported in the *Journal de Paris* (1804) and in the London newspapers.

The Scots Magazine (1804c) had to preface its main article about Juno with a disclaimer, since it had erred by publishing an account of the pseudo-planet Hercules earlier in the year:

Having in a former number laid before our readers an account of the discovery of a new planet, which has turned out to be false, they will probably be disposed to receive with hesitation any notice of a similar kind. We can assure them, however, that a New PLANET was discovered by Mr. Harding, of the observatory of Lilienthal, near Bremen, on the evening of Sept. 1st 1804. Mr. Harding was employed in constructing an atlas of all the stars down to the eighth magnitude, which lie within and near the orbits of the two new planets Ceres and Pallas; and while examining the stars in the constellation Pisces, he observed a small star, of the eighth magnitude, of which he could find no account in the Histoire Celeste of Lalande. Not knowing its true place, he put it down in his maps as accurately as he could estimate with his eye; but two days after, when he looked for it again, he found that it was gone, but perceived another star, exactly like it, a little to the southwest of its place, which did not appear in that place before. Suspecting that this moveable star was a planet,

Göttingische gelehrte Anzeigen

unter der Aufsicht
der königl. Gesellschaft der Wissenschaften.

155. Stück.

Den 29. September 1804.

Göttingen.

Hr. Inspector Harding in Eilienthal hat die königl. Societät der Wiss. benachrichtigt, daß er am 1. Sept. Abends nach 10 Uhr einen neuen Wandelstern im Bilde der Fische entdeckt, und ihn seitdem fast jeden Abend beobachtet habe. "Der Stern, schreibt er, erscheine in einem lebhaften weissen Lichte, hat vollkommen die achte Größe, und bewegt sich, wie es die Theorie, in seiner gegenwärtigen Position, von einem Planeten fordert, rückläufig, mit zunehmender südl. Declination.

"Am 1. Sept., als ich ihn Abends 10 U. 12' zuerst gewahrt ward, schätzte ich seine gerade Aufsteigung $= 2^{\circ} 24'$, und seine nördl. Abweichung $= 0^{\circ} 37'$; den 4. schätzte ich, abermahls nur nach dem Augenmaasse, um 10 U. 20' erstere $2^{\circ} 0'$, und letztere $0^{\circ} 1'$. Den 5., da ich das Kreisnecrometer zur nähern Bestimmung seiner Lage anwandte, fand ich

am 11 U. 12' 45" mittl. B.	die ger. Aufst.	Hel. Abweichung
den 6. 11 U. 26' 48"	$= 2^{\circ} 51' 51''$	$= 0^{\circ} 11' 26''$
— 7. 9 31 37	$= 1^{\circ} 44' 21''$	$= 0^{\circ} 24' 8''$
— 9. 8 42 59	$= 1^{\circ} 36' 58''$	$= 0^{\circ} 36' 36''$
— 10. 8 39 4	$= 1^{\circ} 22' 4''$	$= 0^{\circ} 59' 7''$
— 11. 8 46 46	$= 1^{\circ} 13' 18''$	$= 1^{\circ} 11' 55''$
	$= 1^{\circ} 3' 18''$	$= 1^{\circ} 26' 24''$
		D (7)

Fig. 2.10 The discovery of Juno, as yet unnamed, announced in the September 29, 1804, issue of the GGA

he examined it again on the 5th of September, and perceiving that it had moved farther to the southwest, he found his conjecture verified. This new planet is perfectly similar to Ceres in its light and apparent magnitude. It is surrounded by no nebula, and moves retrograde towards the west with increasing southern declination. The daily motion of the new planet

in right ascension is about 7' 56", or 31".7 in time retrograde; and its daily motion in declination 12' 34" south.

The article also included the right ascension and declination observed by Olbers and Harding from September 1 through 10. It followed up this article with five more (*The Scots Magazine* 1804d, e, 1805a, b and c) that gave observations by Bode from Sept. 21 to Oct. 20, and in 1805 its orbital elements based on the work of Burckhardt. The 1804d article mistakenly reports that the new planet Juno (unnamed) had been discovered by Olbers, thus engendering more confusion between Juno and Hercules.

Here is the detailed report about Juno's orbital elements in *The Scots Magazine* (1805a):

The New Planet lately discovered by Mr. Harding of Lilienthal, had not been seen for the space of a month on account of the badness of the weather. It was observed, however, on the 21st of December, by Burckhardt, who has determined anew the following elements of its orbit.

<i>Ascending node</i>	<i>171° 6' 0"</i>
<i>Inclination</i>	<i>13 5 0</i>
<i>Perihelion in 1805</i>	<i>45 49 33</i>
<i>Epoch 31st Dec. 1814,</i>	
<i>At noon</i>	<i>42 17 23</i>
<i>Eccentricity</i>	<i>0.25096</i>
<i>Larger semiaxis</i>	<i>2.657</i>
<i>Periodical revolution 1582 days.</i>	

From these elements the following places of the Planet have been calculated. [The article then gives eight positions from December 21, 1804, to February 15, 1805.]

From these elements it appears that its periodical revolution, which is four years and four months, is nearly equal to that of Pallas or Ceres, and that the eccentricity of its orbit is greater than that of any of the other planets of the system. The effect of this eccentricity is so sensible, that the time employed by the planet to pass over the first part of its orbit, the middle of which is occupied by its aphelion, is the double of the time necessary for completing the second half. In like manner, its greatest distance from the sun is almost double the least distance. In absolute measures, the difference between these two distances is 45 millions of leagues, or equal to one and a third of the distance of the earth from the sun. The Planet passed its perihelion on the 15th of February.

The *Christian Observer* (1804) published one paragraph, giving the positional data from Olbers (nothing from Harding!) on September 8.

M. Harding, of the Observatory at Lilienthal near Bremen, who has been employed on at atlas of all the stars down to those of the eighth magnitude, which lie within and near the orbits of the two new planets Ceres and Pallas, discovered on the 1st of September a THIRD NEW PLANET. Its place, as settled by Dr. Olbers, on September 8, was at M.T. 8h. 11m. 20 deg. A.R. 1 deg. 29 min. 39 sec. declin. south 0 deg 47 min. 19 sec.: its motion in A.R. is about 7 min. 56 sec., or 31 min. 7 sec. in time retrograde, and in declin. about 12 min. 34 sec. south per diem. It is similar to Ceres in light and apparent magnitude. Nothing nebulous can be distinguished around it; and, in all probability, it is another of a considerable body of small planets, of which this is the third recently discovered. In The Philosophical Magazine for October last, a chart [Fig. 2.11] is given, representing the apparent path of this New Planet, laid down from Observation.

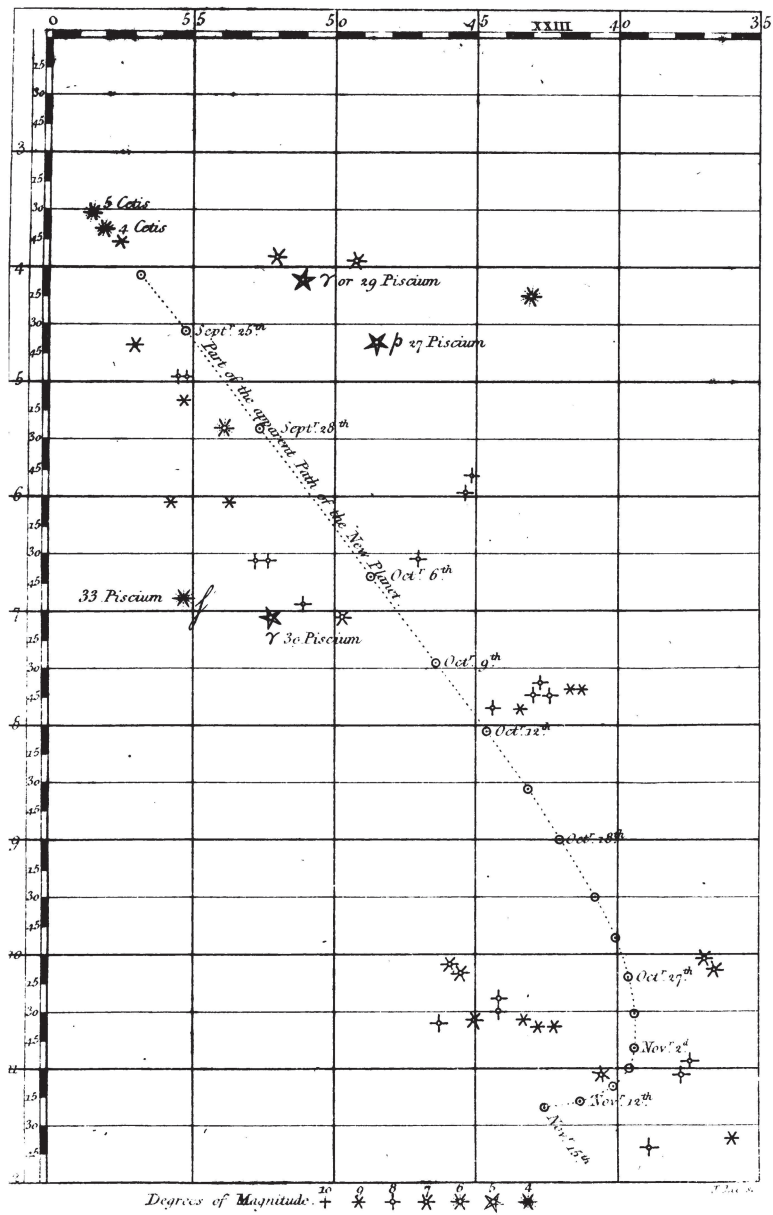


Fig. 2.11 A star chart showing the path of Juno, *Philosophical Magazine* (1804)

The October issue of Tilloch’s journal *The Philosophical Magazine* (1804) was unique in providing a star chart so that its eminent readers might find the new object. It gives a careful explanation on how to use it:

Having been favoured by an eminent astronomer with a chart [Fig. 2.11] representing the apparent path of the new planet, accompanied with the following observations in regard to the use of it, we flatter ourselves it will prove gratifying to our astronomical readers.

The apparent path of the new planet was laid down in this chart from observations made from September 29 to October 12, 1804. The remaining part of the orbit, which is carried on to the middle of November, was laid down on a supposition that the planet's mean distance is about the same as that of Pallas, as the retrograde motion seems nearly to correspond with that of the same planet when near its opposition. It cannot therefore be expected that the orbit laid down in the chart will be very correct: but, as great care has been taken to lay down all the stars as those of the ninth magnitude with as much accuracy as possible, it is hoped this small map will be found particularly useful to those who may not be provided with instruments for taking right ascensions and declinations, but who, being provided with a good telescope, may wish to find it; which by help of this chart and a good general atlas or pair of globes they may easily do, by first finding some of the principal stars and then those of a smaller magnitude, by which they will be enabled to find those laid down in this map; and, by comparing their positions with their apparent places in the heavens, will be soon led to discover the planet by its motion among them. The planet is a little brighter than those marked in the map of the eighth magnitude; and, if the places of these stars be carefully observed, can hardly be mistaken.'

The Philosophical Magazine (1805) continued its look at Juno 5 months later

M. Harding, of Lilienthal, near Bremen, has discovered a new planet, to which he has given the name of Juno. While comparing with the heavens the fifty thousand stars observed by Messrs. Lalande, he saw one of the eighth magnitude, which appeared to him to have a motion of its own. He observed it several days, and soon found that it was a planet. On the 5th of September, its right ascension was $1^{\circ} 52'$. Its north declination $0^{\circ} 11'$. M. Burckhardt observed it on the 23d of September, at $359^{\circ} 7'$, and $4^{\circ} 6'$, and thence concluded that the duration of its revolution is five years and a half. Its inclination is 21° . Its excentricity is a quarter of its radius. Its mean distance from the sun is three times that of the earth, that is to say, it is about a hundred millions of leagues; it is consequently a little farther distant from the sun than Ceres and Pallas, which are only ninety-six millions of leagues. Its diameter has not yet been measured, but it appears like a star of the eighth magnitude. Its size appears nearly equal to that of Ceres, or of the planet discovered by Piazzi. As astronomers daily observe it, more precise elements of it may be obtained. Juno is the 12th planet discovered within a small number of years. Herschel discovered Uranus, and its six satellites; he discovered also two new satellites to Saturn; Piazzi discovered Ceres; Olbers discovered Pallas; and Harding has discovered Juno.

A report with nearly the identical words was published in *The Gentleman's Magazine* (1805). A slightly rewritten version of the article in Tilloch's journal was also published in *The Universal Magazine* (1805), an example of how information was shared. *The British Critic* (1805) kept its readers informed in great detail about Juno. It devoted three pages to a description of Herschel's 1805 Juno paper in the *Philosophical Transactions*, without offering any commentary about it.

Nicholson's *A Journal of Natural Philosophy* was a widely read publication. One of its contributors was Augustus Frederick Thøeiden (died 1823) who lived at No. 10, St. Albans Street, Pall Mall. He was personally acquainted with Bode, who sent him letters, which were then printed by Nicholson. A letter from Bode to Thøeiden dated September 18, 1804 gives readers of *A Journal of Natural Philosophy* (1804a) their first notice of the discovery of Juno:

On the first of September Mr. Harding discovered, at Lilienthal, a new moveable star; it appears to be of the eighth magnitude; its motion retrograde towards the South. Probably this may be another new planet in the orbit of Ceres and Pallas.

This journal then prints the observational data from September 1 through 10. Thoelden appends his own sentence to conclude the brief article: “The two last observations were made by Dr. Olbers, at Bremen. I received this intelligence yesterday, but at present this small planet (there are now three) is not discoverable, on account of the moon-shine.” (Thoelden 1804:143).

The same issue also gives notice of the discovery from the English scientist Thomas Young (1773–1829; 1804:112–113), in a letter dated September 22, 1804. This also lets us know letters from Germany to England could take roughly 10 days in transit.

I have just received a letter from Dr. Gauss of Brunswick, F.R.S. dated September 11, in which he informs me that, a few days before, Mr. Harding at Lilienthal had discovered ‘a new moving star, most probably another new planet of our solar system.’ Dr. Gauss is certainly a person on whose judgment much dependence may be placed: He has sent some further particulars of the discovery to the Astronomer Royal.

In a letter from Bode dated October 23, 1804, Bode sends Thoelden positional measurements from September 21 to October 20. Thoelden sends this information to Nicholson in a letter of November 3, which he duly prints: “I herewith transmit to you,” says Bode, “some of my own observations of the new discovered third planet, (which is to be called Juno) made at our Observatory.” (*A Journal of Natural Philosophy* 1804b).

The *Journal* kept reporting asteroid data years later. The 1809 issue, for example, contains observations of Pallas, Juno and Vesta by Olbers and Gauss. Even the complete orbital elements are printed (*A Journal of Natural Philosophy* 1809).

In Philadelphia, *The Evening Fire-side* (1805) carried news about the discovery of Juno in its very first volume. The *Monthly Anthology and Boston Review* (1805) printed the same article:

Another new planet has been discovered by M. Harding, of Lilienthal, near Bremen, to which he has given the name of Juno. It is of the eighth magnitude, and attracted his attention, while comparing with the heavens the 50,000 stars observed by Lalande. It appears to have a peculiar motion, and, after observing it for several days, he clearly ascertained that it was a planet. The same planet was observed by M. Burckhardt, who makes its annual revolution to be five years and a half. The following particulars have also been ascertained: Its inclination is 21 deg. Its eccentricity is a quarter of its radius. Its mean distance from the sun is three times that of the earth, or about an hundred millions of leagues; it is consequently farther than Ceres or Pallas, whose distance is ninety-six millions. Its diameter has not yet been ascertained; but its size appears nearly the same as that of Ceres, or the planet discovered by Piazzi. This is the twelfth planet discovered within a few years, Herschel having discovered Uranus and its six satellites, and two new satellites to Saturn; Piazzi discovered Ceres; Olbers discovered Pallas.

In the early nineteenth century, the reading public must have been somewhat confused by the terminology associated with the recent discoveries. Different publications had their own views on what constituted a planet. In the example just quoted we see satellites of primary planets, a primary planet, and the asteroids, all lumped into the general category of planets. The passage is also a good indication of the level of knowledge being imparted to the reading public about the discovery of Juno – an estimate of its size compared with Ceres, and the relevant figures of its orbital

elements. *The Monthly Magazine* (1804) also communicated news about Juno to its readers:

On the 21st of September, about eleven o'clock at night, Mr. Bode, in the Observatory at Berlin, had a view of the new planet first discovered by Mr. Inspector Harding, at Berlin, on the 1st of September. Its nearing was east-by-north, 14. of the Whale, according to Mr. Bode's catalogue of the stars. It appeared as a planet of the seventh magnitude. He calculated its meridian altitude at 11h. 55' 21"; its apparent right ascension at $359^{\circ} 27' 46''$; its south declination $3^{\circ} 38' 23''$. He considers it as a planet not known before Mr. Harding's discovery, and belonging to the region of Ceres and Pallas.

The same publication keeps its readers informed about the works of Gauss and Schroeter:

M. Gauss, already known as one of our greatest astronomers, has undertaken to calculate the attractions of Jupiter on the three new planets; but as there will be several hundred equations, he purposes to give only the methods by which our calculators may easily determine the quantities of those equations. A work, entitled Lilienthalische Beobachtungen der neu entdeckten Ceres, Pallas, und Juno; or Observations made at Lilienthal, on the recently discovered Planets Ceres, Pallas, and Juno, by Dr. J. H. Schroeter, 336 pages, 8vo. gives the observed diameters, but which appear too large according to the memoir of Herschel. He finds the first, or Piazzi, 3,"5, if the distance be taken at one; diameter 587 leagues; the second, or Olbers, 4,"5; diameter 760 leagues; the third, or Harding, 3,"1; diameter 515 leagues. (The Monthly Magazine 1806)

Yet another London publication, *Retrospect of Philosophical, Mechanical, Chemical and Agricultural Discoveries* (1806) published a report about Juno that came from the French *Journal de Physics*.

More particular accounts have been received respecting the new planet Juno, discovered last year by Mr. Harding, of Lilienthal, near Bremen.

On the 5th of September its right ascension was $1^{\circ} 52'$. Its declination $0^{\circ} 11'$. North. Mr. Burckhardt observed it on the 23d September at $359^{\circ} 7'$, and $4^{\circ} 6'$, whence he concludes that the duration of its revolution is five years and a half: its inclination is 21° : eccentricity one quarter of its radius; mean distance from the sun, three times greater than that of the earth, that is to say, about a hundred millions of leagues: it is consequently a little farther from the sun than Pallas. Its diameter has not been measured; but it appeared like a star of the eighth magnitude, and nearly equal to Ceres. Juno is the twelfth planet discovered within a small number of years.

One of the London journals designed to appeal to intelligent ladies makes an appearance here. *La Belle Assemblée* (1807:89) published a lecture on astronomy by Margaret Bryan (1806), which was part of her *Lectures on Natural Philosophy*. Bryan ran a boarding school for girls in Blackheath, London, from 1795 to 1806, where the curriculum included mathematics and sciences – rarely offered to young women. She published her lecture notes on astronomy in 1797, and after their positive reception she decided to undertake another such volume, which resulted in the book just mentioned. Half a page is devoted to Ceres, Pallas and Juno. She adopts the French style of naming. “The two first discovered are called Piazzi and Olbers, after the names of their discoverers.” She also gets the name of the discoverer of Juno wrong, calling him Hardinge, but does give credit to Herschel for naming the new objects asteroids.

Another way for people to learn about Juno was the public display of orreries. A very early example that included just the first three asteroids was constructed by a certain Mr. Espy of Grenoble. A report in *Miscellen für die neueste Weltkunde* (1807), a twice-weekly publication in Basel, Switzerland edited by Heinrich Zschokke (1771–1848), reports “The instrument, which is the size of a large table pendulum, gives a very vivid idea of our solar system and its movements. The planets, among which are Ceres, Pallas, and Juno, are shown rolling around the sun in their astronomical periods.” This instrument (termed in the German article a ‘Planetarium’) was shown in Paris in the spring of 1807.

An annual American almanac, *Peter Parley’s*, regularly included the asteroids in its monthly list of astronomical events. Fig. 2.12 shows an example from April 1836.

PARLEY'S ALMANAC.		39
APRIL.		
Days of Month.	Astronomical Phenomena, Remarkable Days, &c.	Chronology.
1	Occ. θ π 11h. 41m. a.	Bonaparte mar. to Maria Louisa, daughter
2	π 's'th 11h. 10m. a. R.A. 11h. 50m. N.D.	Jefferson born 1743. [of Francis II, 1810.
3	Ecl. π Sat. 10h. 43m. a. δ ζ ζ . [14° 11'.	Bp. Heber d. 1826, $\mathcal{A}$. 43. [d. 1831, $\mathcal{A}$. 82.
4	ζ Perigee 9h. m. Fair	Oliver Goldsmith d. 1774. Isaiah Thomas,
5	Shad. on π 10h. 59m. a. with frost.	1621, Gov. Carver, d. at Plymouth, Mass.
6	Ecl. π Sat. 9h. 26m. a. High Tides.	1817, Caleb Bingham, d. at Boston, Mass.
7	ζ sets 10h. 12m. a. Fair.	1807, Lalande d. at Paris, aged 75. [$\mathcal{A}$. 60.
8	Occ. τ π 11h. 43m. a.	1364, John, king of France, died.
9	Cool and [13° 35'.	1626, Lord Bacon died, aged 66. [$\mathcal{A}$. 73.
10	ζ sets 9h. 37m. R. A. 7h. 6m. N. D.	1806, Gen. Gates d. 1736, Prince Eugene d.
11	π δ ζ . windy.	1814, Bonaparte abd. the throne of France.
12	π sets 9h. 44m.	1765, Edward Young died.
13	Ecl. π Sat. 11h. 21m. a. δ ζ ζ .	1748, Christopher Pitt died, aged 49.
14	Shad. on π 7h. 59m. a. Rather cool.	1759, George Frederick Handel died.
15	π souths 9h. 23m. Middling Tides.	1632, Geo. Calvert died, $\mathcal{A}$. 50. [Ms. died.
16	Time for April showers.	1644, Wm. Brewster, 1st min. of Plym. col.
17	Shad. on π 9h. 15m. a. ζ δ ζ .	1790, B. Franklin d. at Philadelphia, $\mathcal{A}$. 84.
18	Shad. on π 10h. 20m. a. ζ Apog. 5h. m.	1802, Erasmus Darwin died.
19	π δ ζ . Rain, perhaps	1775, Bat. of Lexington, Ms. Byron d. 1824.
20	Ecl. π Sat. 7h. 45m. a. snow.	1831, Dr. Abernethy died, aged 67.
21	Low Tides.	323 B. C. Alexander the Great died, $\mathcal{A}$. 33.
22	π rises 2h. 53m.	1715, Great Eclipse of the Sun.
23	Rain or [16° 21'.	1702, Qn. Anne crowned at Westminster.
24	ζ rises 9h. 21m. R.A. 21h. 15m. N.D.	1798, Elz. Wheelock, d. at Hanover, N. H.
25	snow.	1832, Bap. Conv. of U.S. at New York city.
26	Ecl. π Sat. 9h. 41m. a.	1775, Josiah Quincy died at sea, aged 31.
27	Rather cool.	1794, Js. Bruce died. Sir W. Jones d. $\mathcal{A}$. 48.
28		1758, James Munroe born.
29		1827, Rufus King died, aged 73.
30		1789, Washington inaug. Pres. of the U.S.

Fig. 2.12 Entry for Juno in *Peter Parley’s Almanac* for April 1836

The listing for Juno appears for the April 10 entry, telling when it sets in right ascension and north declination. Pallas makes an appearance on April 26, with its position of rising. The remarkable thing about this is that no one without a fine telescope could make use of these figures, so it shows that the significance placed upon the asteroids in the 1830s was substantial.

Although publications in several countries thus disseminated news of Juno, the sheer breadth of publications combined with a large body of literate people singles out both England and Scotland as the places where the news of the asteroid discoveries were most widely known.

It is quite apparent that the function and province of Science was a large one in the eyes of Englishmen; the function varied as the individual demands were made upon it. Broadly, the progressive spirit of science was what made it attractive to the average man, coupled with its capacity to meet immediate needs, whether of a utilitarian or humanitarian nature. At the same time, the better informed man, regarding science in broader aspects and in truer terms, saw it as a tool which, if used wisely, could broaden the periphery of man's knowledge.
(Foote 1954:454)

Though George Foote of Wayne University in Detroit mentions only men, the scope must be widened to include women as well, since several books referenced in this series include those specifically geared to the education of ladies in the early nineteenth century.

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